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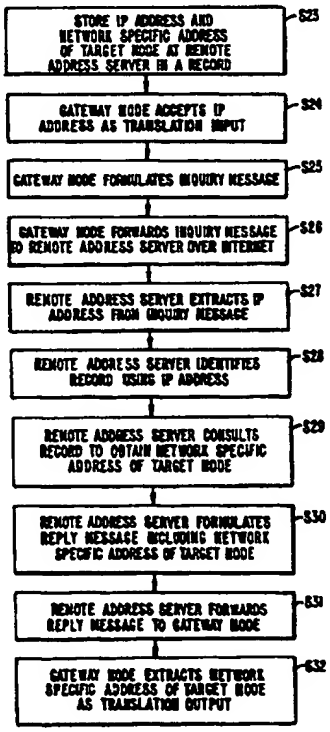
(54) Title: METHOD FOR TRANSLATING INTERNET PROTOCOL ADDRESSES TO OTHER DISTRIBUTED NETWORK ADDRESSING SCHEMES

(57) Abstract

In a local network (2, 4, 12, 20) connected to other networks (2, 4, 12, 16, 20) which employ an Internet Protocol, and wherein the local network includes nodes (A, B, C, D, E, F, N, O, P, Q, R, S, 8, 18) which cannot monitor all other nodes in the local network, an Internet Protocol address of a target node (18) in the local network is translated at a gateway node (14) in the local network to a network-specific local address of the target node (18) without the use of broadcasting. The network specific local address of the target node (18) is the address which is usable within the local network for forwarding a packet to the target node (18).



METHOD FOR TRANSLATING INTERNET PROTOCOL ADDRESSES TO OTHER DISTRIBUTED NETWORK ADDRESSING SCHEMES

BACKGROUND OF THE INVENTION

This invention relates generally to a method for translating addresses between the addressing scheme determined by the Internet Protocol and another addressing scheme used by a data communication network.

The Internet Protocol is a widely used protocol for the transmission of data communication packets over a network of participating digital communication networks. The operation of the Internet Protocol is described in detail in Stallings, Handbook of Communication Standards vol. 3 (1990), a generally-available reference in the field, the contents of which are herein incorporated by reference. One example of a network of networks which operates according to the Internet Protocol is the Internet, a global network of networks which operates with decentralized management. Herein, all interconnected networks of networks which operate according to the Internet Protocol are referred to as internets.

Figure 1 depicts an exemplary internet which comprises a first local area network (LAN) 2, a second LAN 4 and a long haul network 6 which allows for packets to be communicated between the LANs. Host nodes A through F and gateway node G are connected to LAN 2. Host nodes H through L and gateway node M are connected to LAN 4. Each host node and gateway node possesses a unique local network address known as a Medium Access Controller (MAC) address. The MAC address is uniquely assigned to each node and does not depend on the identity of the network to which the node is connected. LANs 2 and 4 are not limited to any specific topology but operate to allow a data communication packet to be forwarded from a source node connected to the network to any target node

node. However, the Internet Protocol does not require that the MAC address be included in a header of the packet when it is received at gateway node M, which as herein explained can present problems.

The gateway node M may already be aware of the MAC address of host node N and may then forward the packet to host node N using the MAC address. If the gateway node M is unaware of the MAC address of the host node N it typically determines the MAC address by a method known as the Address Resolution Protocol (ARP). The ARP exploits the broadcast property of an LAN: namely, that a transmission from any node on the network is received by all other nodes on the network.

The gateway node M thus determines the MAC address of the target node N using the ARP as follows. The gateway node M broadcasts over the LAN 4 an inquiry message containing the IP address of the target node N. The target node N then responds with a reply message containing as a matched pair both its own MAC address and its own IP address. The gateway node M stores the paired MAC address and IP address in a local routing table at the gateway node M. The packet may then be forwarded to the target node N by including the MAC address in a header of the packet. Packets received at the gateway node and addressed to the IP address of the target node are henceforth forwarded using the MAC address stored in the local routing table at the gateway node.

The ARP thus allows a packet forwarded over an internet and received at a gateway node connected to a local network to be forwarded to the target node to which the packet is directed. However, only networks with certain properties may effectively use the ARP. For example, the network should have the broadcast property typically associated with LANs, that is, the network must be physically configured so that each node can directly receive an inquiry message broadcast over the network. If one or more nodes within the LAN cannot directly receive an inquiry message, further relaying of the inquiry message will be required at an increased expense in network resources. Frequent ARP inquiry messages will

addressed. Therefore, expensive ARP inquiry messages are likely to be very frequent. Furthermore, a mobile node may be unaware of its own IP address and thus be unable to respond to an ARP inquiry message.

A further difficulty arises in networks which use certain geographical routing methods for forwarding packets. A geographical routing method is disclosed in U.S. Pat. No. 4,939,726, which is herein incorporated by reference. In a network which makes use of the therein disclosed geographic routing method, a packet is typically forwarded from a source node to a target node via a series of intermediate nodes. The address of the target node is included in a header of the packet. The disclosed method requires that packet addresses incorporate the geographic coordinates of the target node. Each intermediate node typically selects a successor intermediate node based on the maximum forward progress attainable using the least amount of power. Forward progress is determined by calculating a metric incorporating the geographical distance between the geographic coordinates of the target node and the geographic coordinates of each node to be evaluated for selection as a successor intermediate node. The geographic coordinates of the target node are derived from the address of the target node found in the header of the packet. Thus, retrieving the MAC address of the target node, as is accomplished by the ARP, will be insufficient to relay a packet to the target node over such a network, because the MAC address does not contain any information about the geographic coordinates of the target node.

Another difficulty arises when storage at the gateway node is limited so that only a restricted number of pairings of IP addresses and network specific local addresses is retained. If the ARP method for translation is used, repeated broadcasts may be necessary as pairings are lost or overwritten.

It is desirable to send packets from a source node connected to an originating network which participates in an internet to a target node connected to a destination network which participates in the same internet where the

target node is the address which is usable within the local network for forwarding a packet to the target node.

According to a first aspect of the invention, the translation at the gateway node is accomplished by consulting a record stored at the gateway node which contains both the network specific local address and IP address of the target node. In one scheme, this record is created by self-registration. The target node self-registers by contacting the gateway node and sending the gateway node the target's own IP address and network specific local address.

Alternatively, the record stored at the gateway node is created by assignment. Under this scheme, the target node contacts the gateway node and sends to the gateway node its own network specific local address. The gateway node then assigns the target node an IP address. Under either scheme, a record is stored at the gateway node which can later be used for translation.

A second aspect of the invention takes advantage of the collection function employed by a remote address server. The remote address server which is typically not on the local network, but which is in communication with the gateway node over an internet, captures network specific local address and IP address information about nodes of which it becomes aware. For each node of which the remote address server becomes aware it creates a record containing the network specific local address and IP address of the node. For example, a reporting node may employ an internet to self-register by reporting its own network specific local address and IP address to the remote address server. Alternatively, an operator may enter the IP address and network specific local address of a node into the remote address server.

According to the second aspect of the invention, the translation at the gateway node is alternatively accomplished by consulting a record stored at the remote address server containing the network specific local address and IP address of the target node. The gateway node accesses the record by formulating an inquiry message which includes the IP address of the target node and then by forwarding the message to the

Fig. 4 is a flow chart describing steps of an address assignment and translation method according to the invention.

Fig. 5 is a flow chart describing how a packet may be forwarded via an internet according to the invention.

Fig. 6 is a flow chart describing steps of an address translation method employing a remote address server according to the invention.

Fig. 7 is a flow chart describing steps of a packet forwarding method employing a remote address server according to the invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Figure 2 depicts an internet which may take advantage of the address translation method of the invention. Source node 8 and gateway node 10 are connected to local network 12. Gateway nodes 10, 14 are connected to long haul network 16. Gateway node 14 and target node 18 are connected to local network 20. In accordance with the invention, a remote address server 22 is accessible via the internet and is connected to long haul network 16.

Figure 3 is a flow chart illustrating steps of an address translation method in accordance with the invention. A record for address translation is created by self-registration. Target node 18 is aware of its own IP address and its own network specific local address usable for forwarding a packet over local network 20. The network specific local address need not be a MAC address and may incorporate the geographic coordinates of the target node. Gateway node 14 is contacted by target node 16 (Step S1). A data communication link is established between gateway node 14 and target node 18 which permits data communication between the nodes (Step S2).

Target node 18 then transmits a message to gateway node 14 over the link which includes the IP address and network specific local address of target node 18 (S3). The IP address and network specific local address are stored as a

gateway node 14 (S13). Target node 18 thus now has an IP address of which it is aware. Gateway node 14 translates from the IP address of target node 18 to the network specific local address of target node 18 in the same way discussed in connection with Figure 3 (S14-16).

Figure 5 is a flowchart illustrating steps of a packet forwarding method according to the invention. By this method, a packet may be forwarded from source node 8, connected to originating local network 12, to target node 18 connected to destination local network 20. A record containing the network specific local address and IP address of target node 18 is created and stored at gateway node 14 according to one of the inventive address translation methods depicted in Figures 3 and 4.

The packet forwarding method of the invention takes advantage of the method specified by the Internet Protocol for forwarding packets over an internet. Source node 8 includes the IP address of target node 18 in a header of the packet to be communicated (S17). Source node 8 then forwards the packet to gateway node 14 through local network 12, gateway node 10 and long-haul network 16 employing the method specified by the Internet Protocol (S18).

In accordance with the invention, upon receipt of the packet at gateway node 14, gateway node 14 extracts the IP address from the packet (S19). Gateway node 14 then translates the IP address of target node 18 to the network specific local address usable for forwarding packets over local network 20 (S20). The translation is accomplished by using the extracted IP address of the target node as the translation input of either of the inventive methods depicted in Figures 3 and 4.

Gateway node 14 then includes the network specific local address of target node 18 obtained by translation in a header of the packet (S21). Finally, the packet is forwarded to target node 18 using the network specific local address (S22). If the network specific local address incorporates the geographic coordinates of target node 18, the packet may be forwarded from gateway node 14 to target node 18 according to

record to obtain the network specific local address of the target node (S29) and formulates a reply message which includes the network specific local address of target node 18 (S30). The reply message is then forwarded to gateway node 14 over long-haul network 16 (S31). Gateway node 14 extracts the network specific local address from the reply message (S32) and the extracted network specific local address is the translation output.

Figure 7 illustrates the steps of a packet forwarding method which makes use of the remote address translation method described in Figure 6. By this method, a packet may be forwarded from source node 8, connected to originating local network 12, to target node 18, connected to destination local network 20.

According to the inventive method, source node 8 includes the IP address of target node 18 in a header of the packet to be communicated (S33). Source node 8 then forwards the packet to gateway node 14 using the method specified by the Internet Protocol (S34).

In accordance with the invention, upon receipt of the packet at gateway node 14, gateway node 14 extracts the IP address from the packet (S35). To obtain the network specific local address of target node 18, gateway node 10 accesses remote address server 22 according to the method described in Figure 6 (S36) using the extracted IP address as the translation input. Gateway node 14 then includes the network specific local address in a header of the packet (S37) and forwards the packet to target node 18 over local destination network 18 (S38).

If the network specific local address incorporates the geographic coordinates of the target node, the packet may be forwarded from the gateway node to the target node according to the geographic routing method disclosed in U.S. Patent No. 4,939,726.

In an embodiment of the invention which combines the packet forwarding methods of Figures 4 and 6, the gateway node first attempts to translate the IP address of the target node by the method described in Figure 4, that is by consulting a

WHAT IS CLAIMED IS:

1. In a data communication system comprising a plurality of interconnected networks, a method for translating an Internet Protocol (IP) address to a network-specific local address useable for forwarding a packet over a local network the method comprising the steps of:

using a first node to contact a second node where both said first node and said second node are connected to said local network; thereafter

establishing a communication link between said first node and said second node; thereafter

transmitting from the first node to the second node over said communication link a self-registration message comprising an IP address of said first node and a network specific local address of said first node, said network specific local address being usable to forward a packet to said first node over said local network; and thereafter

extracting, at said second node, said network specific local address and said IP address of said first node from said self-registration message; and

storing in a memory device at said second node a record comprising said IP address of said first node and said network specific local address of said first node obtained in said extracting step.

2. The method of claim 1 wherein said network specific local address of said first node incorporates the geographic coordinates of said first node.

3. The method of claim 1, said method further comprising the steps of:

accepting at said second node said IP address of said first node as a translation input;

identifying said record at said second node using said accepted IP address; and

6. The method of claim 4, said method further comprising the steps of:

accepting at said second node said IP address of said first node as a translation input;

identifying said record at said second node using said accepted IP address; and

consulting said record identified in said identifying step to obtain said network specific local address of said first node as a translation output.asd;flkj

7. In a data communication system comprising a plurality of interconnected networks, a method for forwarding a packet from a first node connected to an originating network to a second node connected to a destination network, said method comprising the steps of:

using the second node to contact a third node, said third node being connected to said destination network; thereafter

establishing a communication link between said second node and said third node; thereafter

transmitting from the second node to the third node over said communication link a self-registration message comprising an IP address of said second node and a network specific local address of said second node, said network specific local address being usable to forward a packet to said second node over said destination network; thereafter

extracting, at said third node, said IP address and said network specific local address of said second node from said self-registration message;

storing in a memory device at said third node a record comprising said IP address of said second node and said network specific local address of said second node obtained in said extracting step;

inserting, at said first node, said IP address of said second node, obtained in said consulting step, in a header of said packet; thereafter

forwarding said packet from said first node to said third node using a method specified by the Internet Protocol;

storing in a memory device at said third node a record comprising said IP address assigned to said second node and said network specific local address of said second node;

transmitting from said third mode to said second node a message including said IP address assigned to said second node; thereafter

inserting at said first node said IP address assigned to said second node in a header of said packet; thereafter

forwarding said packet from said first node to said third node using the method specified by the Internet Protocol;

extracting, at said third node, said IP address of said target node from said packet; and thereafter

identifying said record at said third node using said IP address extracted from said packet;

consulting said record identified in said identifying step to obtain said network specific local address of said target node;

inserting at said third node said network specific local address of said second node obtained in said consulting step in a header of said packet; and thereafter

forwarding said packet from said third node to said second node over said destination network.

10. The method of claim 9 wherein said network specific local address of said second node incorporates the geographic coordinates of said second node and the forwarding of said packet from said third node to said second node is accomplished according to a geographic routing method.

11. In a data communication system comprising a plurality of interconnected networks, a method for translating an Internet Protocol (IP) address to a network specific local address usable for forwarding a packet over a local network the method comprising the steps of:

storing in a memory device at a first node a record comprising an IP address of a second node connected to said

storing, in a memory device at a third node, a record comprising an IP address for said second node and a network-specific local address for said second node for forwarding packets over said destination network to said second node, said third node being disconnected from said local network and accessible via an internet; thereafter

inserting at said first node said IP address of said second node in a header of said packet; thereafter

forwarding said packet from said first node to a fourth node connected to said destination network using the method specified by the Internet Protocol; thereafter

extracting at said fourth node said IP address of said second node from said packet; thereafter

formulating an inquiry message at said fourth node, said inquiry message comprising said IP address of said second node extracted from said packet;

forwarding said inquiry message from said fourth node to said third node over said internet;

extracting at said third node said IP address of said second node from said inquiry message; thereafter

identifying said record at said third node using said IP address extracted from said inquiry message;

consulting, at said first node, said record identified in said identifying step to obtain said network specific local address of said second node;

formulating a reply message at said third node, said reply message comprising said network specific local address of said second node obtained in said consulting step;

forwarding said reply message to said fourth node over said internet;

extracting at said fourth node said network specific local address from said reply message;

inserting at said fourth node said network specific local address of said second node extracted from said reply message in a header of said packet; and thereafter

forwarding said packet from said fourth node to said second node over said destination network.

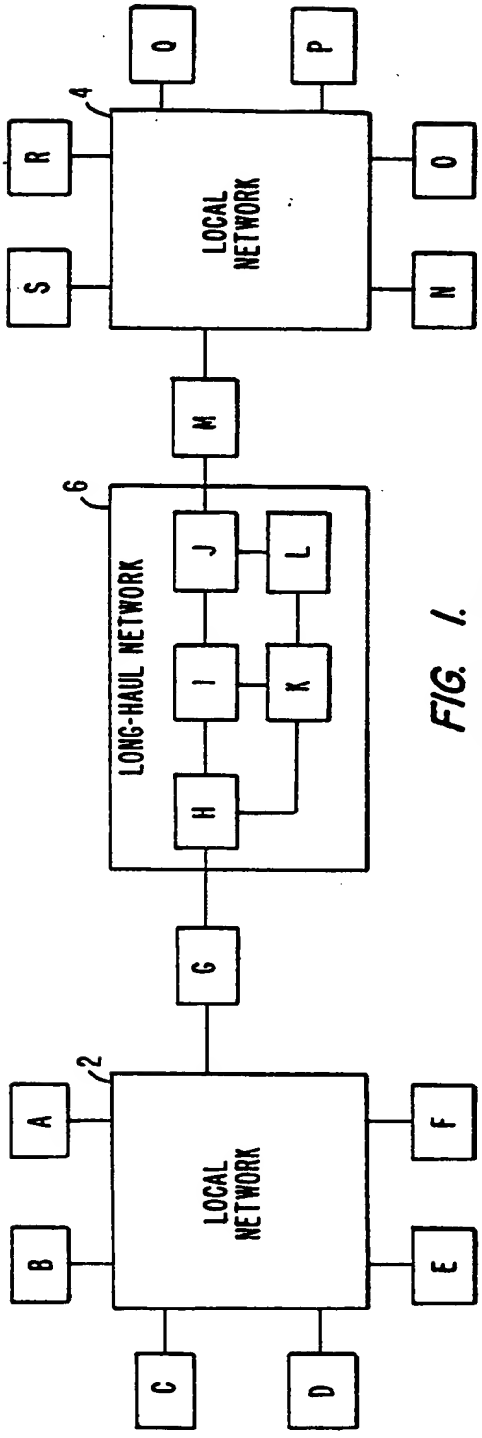


FIG. 1.
(PRIOR ART)

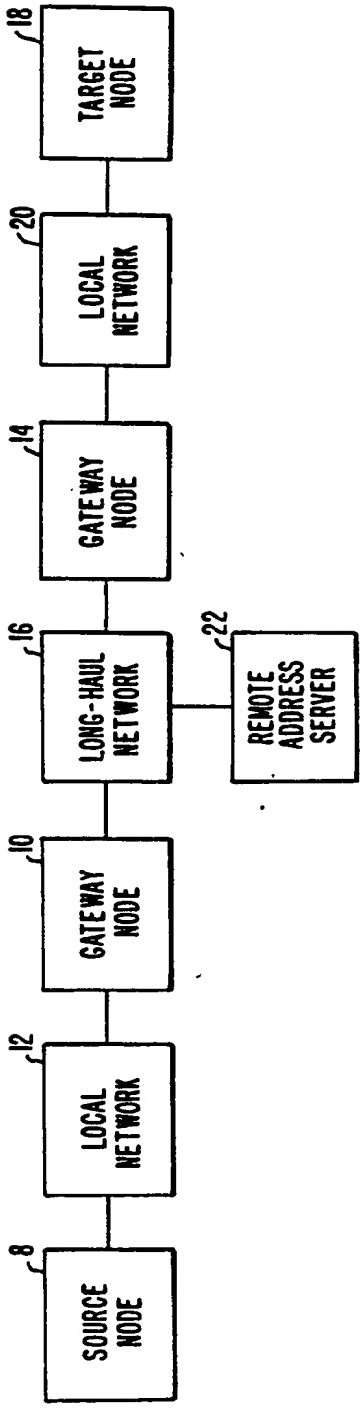


FIG. 2.

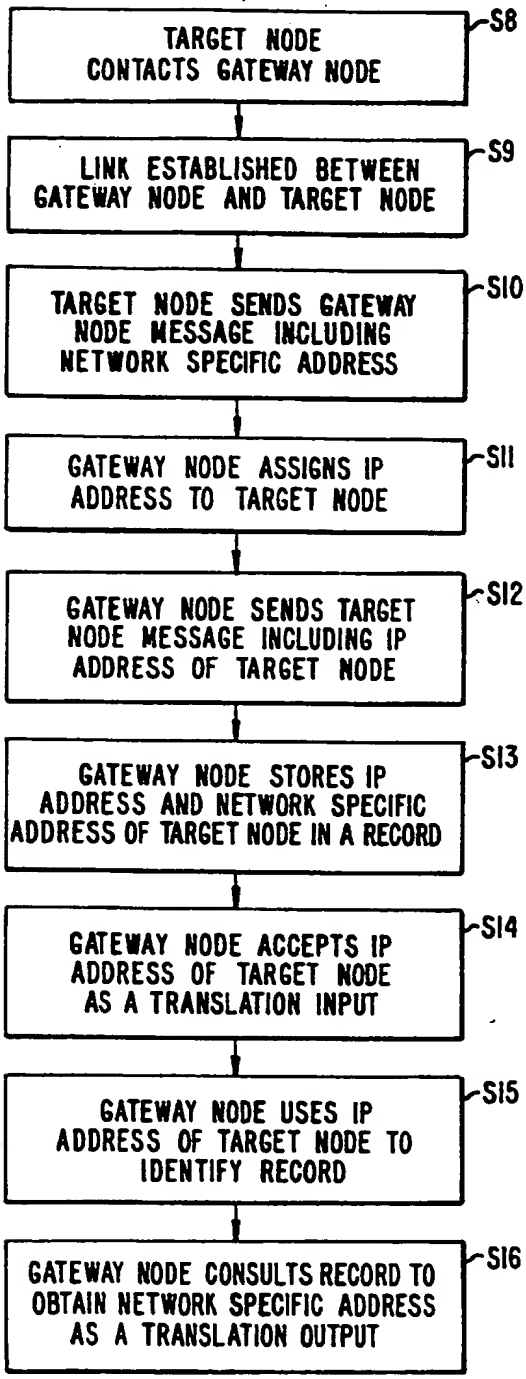

TARGET NODE CONTACTS GATEWAY NODE
S8
LINK ESTABLISHED BETWEEN GATEWAY NODE AND TARGET NODE
S9
TARGET NODE SENDS GATEWAY NODE MESSAGE INCLUDING NETWORK SPECIFIC ADDRESS
S10
GATEWAY NODE ASSIGNS IP ADDRESS TO TARGET NODE
S11
GATEWAY NODE SENDS TARGET NODE MESSAGE INCLUDING IP ADDRESS OF TARGET NODE
S12
GATEWAY NODE STORES IP ADDRESS AND NETWORK SPECIFIC ADDRESS OF TARGET NODE IN A RECORD
S13
GATEWAY NODE ACCEPTS IP ADDRESS OF TARGET NODE AS A TRANSLATION INPUT
S14
GATEWAY NODE USES IP ADDRESS OF TARGET NODE TO IDENTIFY RECORD
S15
GATEWAY NODE CONSULTS RECORD TO OBTAIN NETWORK SPECIFIC ADDRESS AS A TRANSLATION OUTPUT
S16

FIG. 4.

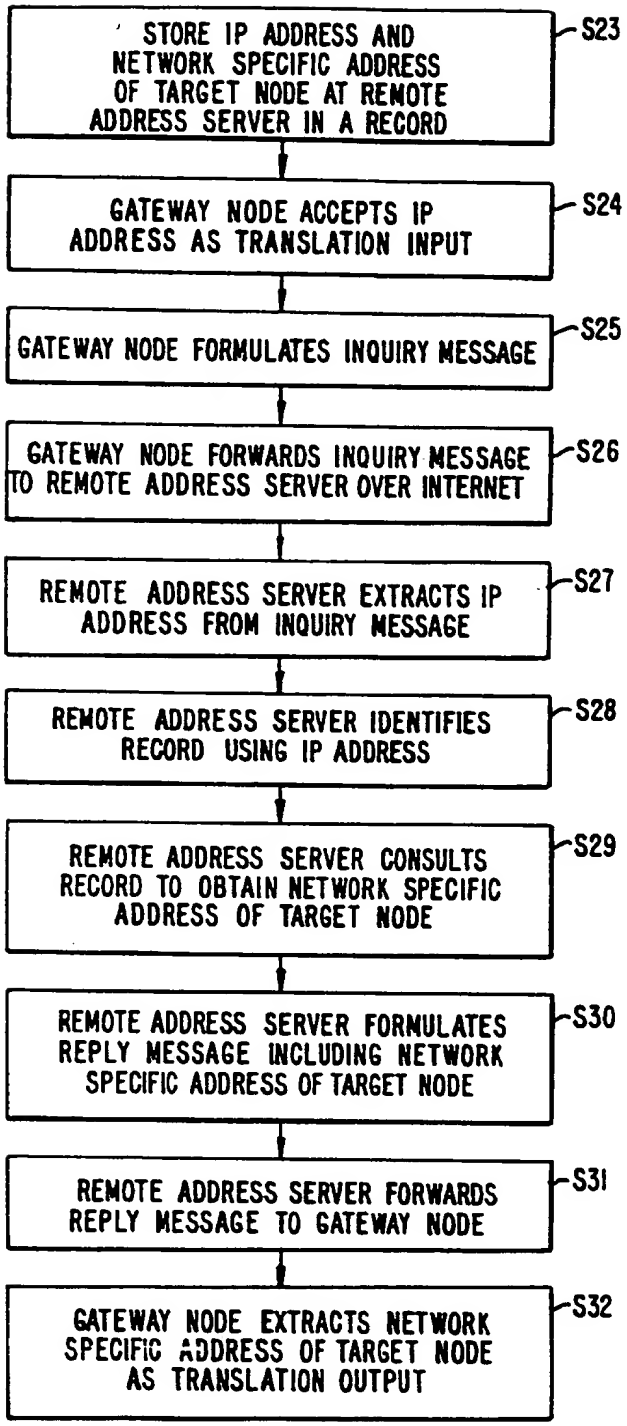

STORE IP ADDRESS AND NETWORK SPECIFIC ADDRESS OF TARGET NODE AT REMOTE ADDRESS SERVER IN A RECORD
S23
GATEWAY NODE ACCEPTS IP ADDRESS AS TRANSLATION INPUT
S24
GATEWAY NODE FORMULATES INQUIRY MESSAGE
S25
GATEWAY NODE FORWARDS INQUIRY MESSAGE TO REMOTE ADDRESS SERVER OVER INTERNET
S26
REMOTE ADDRESS SERVER EXTRACTS IP ADDRESS FROM INQUIRY MESSAGE
S27
REMOTE ADDRESS SERVER IDENTIFIES RECORD USING IP ADDRESS
S28
REMOTE ADDRESS SERVER CONSULTS RECORD TO OBTAIN NETWORK SPECIFIC ADDRESS OF TARGET NODE
S29
REMOTE ADDRESS SERVER FORMULATES REPLY MESSAGE INCLUDING NETWORK SPECIFIC ADDRESS OF TARGET NODE
S30
REMOTE ADDRESS SERVER FORWARDS REPLY MESSAGE TO GATEWAY NODE
S31
GATEWAY NODE EXTRACTS NETWORK SPECIFIC ADDRESS OF TARGET NODE AS TRANSLATION OUTPUT
S32

FIG. 6.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/03810

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 13/14
US CL : 395/200, 275
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/200, 275; 370/60, 94.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,185,860 (WU) 09 FEBRUARY 1993, column 4, line 58 - column 5, line 65.	1-14
Y	US, A, 5,150,464 (SIDHU ET AL) 22 SEPTEMBER 1992, column 3, lines 24-58, column 9, lines 5-29, and Abstract.	1-14.
Y	US, A, 4939,726 (FLAMMER ET AL) 03 JULY 1990, column 2, line 55 - column 3, line 3, and column 8, lines 33 - 67.	2, 5, 8, 10, 12, and 14.

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
14 JUNE 1995

Date of mailing of the international search report
01 SEP 1995

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